Docket No.: ZTP03P01636

CERTIFICATION

I, the below named translator, hereby declare that: my name and post office address are as stated below; that I am knowledgeable in the English and German languages, and that I believe that the attached text is a true and complete translation of PCT/EP2004/052755, filed with the European Patent Office on November 2, 2004.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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METHOD FOR OPERATING A FREQUENCY CONVERTER CIRCUIT

Description

[001] Method for operating a frequency converter circuit

[002] The present invention relates to a method for operating a frequency converter circuit comprising at least two outputs that are respectively connected to a load, especially an induction coil, wherein a first output is operated at a first switching frequency and a second output is simultaneously operated at a second switching frequency that is different from the first in such a way that noise having a frequency generated by the superposition of the first switching frequency and the second switching frequency is produced.

[003] Modern induction cooking surfaces are usually equipped with two or four induction cooking zones. The induction cooking zones have induction coils which are supplied with high-frequency operating currents by means of converter circuits. It is known to operate two induction coils jointly by means of one converter circuit with two outputs, each of the outputs being connected to an induction coil. Various procedures have been proposed for avoiding or reducing noise when both outputs are operated simultaneously.

[004] Known from DE 196 54 268 C2 is a method for operating the converter circuit where both outputs of the converter circuit are operated in time multiplex so that no noise can occur. The disadvantage of this method is that elaborate triggering and over-dimensioning of the power electronics is required.

[005] If the outputs are not operated in time multiplex and the two induction coils are supplied simultaneously with operating currents at different frequency, noise is produced. It is known to reduce this noise by means of choking coils connected in series to the induction coil. The disadvantage of this method is that the method is not always stable. In addition, the noise can only be damped and the choking coils are required as additional components, making the converter circuit more elaborate.

[006] It is the object of the invention to provide an improved and cost-effective method for operating a converter circuit comprising at least two outputs, especially for an induction cooking surface.

[007] This object is solved by a method for operating a converter circuit having the features of claim 1.

[008] In a converter circuit comprising at least two outputs that are respectively connected to a load, especially an induction coil, a first output is operated at a first switching frequency and a second output is simultaneously operated at a second switching frequency that is different from the first. In this way noise having a frequency generated by the superposition of the first switching frequency and the second switching frequency is produced. The converter circuit is operated in such a way that the frequency of the noise is lower than a first cut-off frequency and/or higher than a second cut-off frequency. This procedure has the advantage that noise can be produced at a frequency that lies outside the human audible range by appropriately selecting the first cut-off frequency and the second cut-off frequency. Furthermore, the induction coils

can be operated at frequencies at which a high efficiency can be achieved. In addition, additional components such as choking coils for reducing the noise can be dispensed with.

[009] According to a preferred embodiment, it is provided that the first switching frequency and/or the second switching frequency are operated in such a way that the frequency of the noise is lower than the first cut-off frequency and/or higher than the second cut-off frequency. The switching frequencies of the outputs can be simply adapted by means of intelligent power switches.

[010] Advantageously an electrical power of at least one of the outputs is regulated by means of a relative switch-on time and/or the switching frequency. Thus, the converter circuit can be operated with the induction coils in such a way that a high efficiency is achieved.

[011] According to a preferred embodiment, it is provided that the first cut-off frequency and/or the second cut-off frequency are determined depending on a level of the noise. In this way, the cut-off frequencies can be adapted to the human audibility threshold so that the noise cannot be perceived.

[012] In particular, the first cut-off frequency and/or the second cut-off frequency are determined depending on a total electrical power of the outputs. The level of the noise depends on the total electrical power of the outputs and the total electrical power can easily be determined. In this way, the cut-off frequencies can be adapted especially easily to the human audibility threshold.

[013] According to a preferred embodiment, it is provided that the first cut-off frequency is 2 kilohertz and/or the second cut-off frequency is 14 kilohertz. For these cut-off frequencies the human audibility threshold is very high so that the level of the noise does not reach the human audibility threshold or only insignificantly exceeds it.

[014] In particular, the invention relates to an induction cooking device such as, for example, an induction cooking surface or a cooker with an induction heating element.

[015] The invention and its further developments are explained in detail hereinafter with reference to drawings:

[016] In the figures

[017] Fig. 1a is a first embodiment of a converter circuit,

[018] Fig. 1b is a second embodiment of a converter circuit,

[019] Fig. 2 is a schematic diagram of possible noise frequencies during operation of the converter circuits according to Figure 1,

[020] Fig. 3 is a schematic profile of the human audibility threshold,

[021] Fig. 4 is a schematic time profile of a period of an output voltage of the converter circuits according to Figure 1 and

[022] Fig. 5 is a schematic diagram of an adaptation of electrical output powers for the converter circuits

according to Figure 1 taking into account a first and a second cut-off frequency.

[023] Figures 1a and 1b are schematic diagrams showing two different embodiments of a converter circuit comprising two outputs or induction coils. Here V designates a voltage source, I1 is a first and I2 is a second induction coil, S1, S2, S3 and S4 are high-frequency switches, CF1 and CF2 are capacitive input filters and C1+, C1-, C2+ and C2- are capacitors. The second embodiment (Fig. 1b) differs from the first embodiment (Fig. 1a) in that two changeover switches R1, R2 are provided for reconfiguring the topology for the case when both induction coils I1, I2 are not switched on or both outputs are not active.

[024] Figure 2 shows a schematic diagram of possible frequencies of the noise during operation of the converter circuits according to Figure 1a or 1b. The first induction coil I1 is operated at a first switching frequency f1 and the second induction coil I2 is operated at a second switching frequency f2 which is higher than the first switching frequency f1. Both switching frequencies f1, f2 lie above a maximum frequency f_{max} which can be perceived by human hearing. In this way, noise produced at the switching frequencies f1 and f2 cannot be heard by humans. As a result of a superposition of the two switching frequencies f1, f2, further noise is produced, for example, at a frequency fS which corresponds to a difference comprising the second switching frequency f2 minus the first switching frequency f1. This frequency fS can lie in a frequency band B which indicates the frequencies perceptible by humans. The noise can have different levels L1, L2, LS at different frequencies f1, f2, fS which is indicated by arrows of

different length at the frequencies f1, f2 and fS in Figure 2.

[025] Figure 3 shows a schematic profile of the human audibility threshold H. Depending on the frequency f, a different minimum noise level L can be perceived by the human hearing which is indicated by the profile of the audibility threshold H in Figure 3. A first cut-off frequency g1 and a second cut-off frequency g2 are determined using the level LS of the noise and its points of intersection with the profile of the audibility threshold H, the first cut-off frequency g1 being lower than the second cut-off frequency g2. The converter circuits according to Figure 1a and 1b are operated according to the invention so that the frequency fS of the noise is lower than the first cut-off frequency g1 or higher than the second cut-off frequency g2. In this way the noise is outside the human hearing range and thus cannot be perceived. The level LS of the predicted noise can, for example, be estimated using the switching frequencies f1, f2 and the electrical powers P1 and P2 supplied to the induction coils. Alternatively, experimental cut-off frequencies g1, g2 can be defined, for example, the first cut-off frequency g1 at 2 kilohertz and the second cut-off frequency g2 at 14 kilohertz.

[026] Parameters for adapting the electrical powers P1, P2 supplied to the induction coils I1, I2 are firstly the switching frequencies f1, f2 and secondly a relative switch-on time D. Figure 4 shows a schematic time profile of a period of a first output voltage UA of the converter circuit according to Figure 1a and 1b. The period 1/f is normalised to unity in Figure 4. The output voltage UA increases during the relative switch-on time D and then decreases slowly again. The electrical powers P1, P2 supplied to the

induction coils I1, I2 are highest for relative switch-on times D of 0.5.

[027] Figure 5 shows a schematic diagram of an adaptation of the electrical output powers P1 and P2 for the two induction coils I1, I2 according to the converter circuits from Figure 1a and 1b taking into account the two cut-off frequencies g1 and g2. For the first induction coil I1, for example, which requires the higher electrical power P1 of the two induction coils I1, I2, the switching frequency f1 is specified as 21 kilohertz for example and the relative switch-on time D is specified as 0.5. The electrical power P2 for the second induction coil I2 is now adjusted by means of the relative switch-on time D and by means of the switching frequency f2 taking into account the two cut-off frequencies g1 and g2. The second switching frequency f2 can lie in a range between the first switching frequency f1 (here 21 kilohertz) and the sum of the first switching frequency f1 and the first cut-off frequency g1 (here 23 kilohertz) and above the sum of the first switching frequency f1 and the second cut-off frequency g2 (here 35 kilohertz). In this way it is ensured that the noise at the frequency fS which is produced from the difference between the second switching frequency f2 and the first switching frequency f1 is not perceived by the human hearing.

[028] Reference list

[029] B frequency band

[030] C1+ capacitor

[031] C1 capacitor

[032] C2+ capacitor

[033] C2 capacitor

[034] CF1 capacitive input filter

[035] CF2 capacitive input filter

[036] D relative switch-on time

[037] f frequency

[038] f_{max} maximum frequency perceived by human hearing

[039] f1 switching frequency of the first induction coil

[040] f2 switching frequency of the second induction coil

[041] fS frequency of the noise

[042] g1 first cut-off frequency

[043] g2 second cut-off frequency

[044] H audibility threshold

[045] I1 first induction coil

[046] I2 second induction coil

[047] L sound level

[048] L1 sound level at the first switching frequency

[049] L2 sound level at the second switching frequency

[050] LS level of noise at fS

[051] P electrical power

[052] P1 electrical power of the first induction coil

[053] P2 electrical power of the second induction coil

[054] R1 changeover switch

[055] R2 changeover switch

[056] t time

[057] U voltage

[058] UA output voltage

[059] V voltage source